SOCKEYE SALMON ESCAPEMENT ESTIMATION

FOR SITKOH LAKE,

1999 AND 2000

by
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ABSTRACT

Sockeye salmon, *Onchorhynchus nerka,* escapement estimates were produced for Sitkoh Lake for years 1999 and 2000 by two methods: 1) adapted Jolly-Seber method, and 2) area under the curve (AUC) method. Data for the study was produced by making several trips to the lake each year during the spawning season. Visual counts and mark recapture studies were performed on each trip. The data yielded a population estimate for the lake at the time of each trip. These population estimates were the data used in the two methods of total escapement estimation.

The population size at the time of each trip was determined by the following procedure. A visual count of the lake was performed. Two counts were noted, a count for the whole lake, and a count for the designated study area. A mark recapture study was performed throughout the study area over a two-day period. The data was used to make a Petersen estimation of the study area population. The Petersen estimate of the study area population divided by the visual count of the study area population provided a factor which adjusts for undercounting. The whole lake visual count was multiplied by this factor to yield an estimate of the whole lake population at that time.

The Jolly-Seber method was adapted by substituting trip population estimates, as detailed above, for the population size estimates that are normally derived by the Jolly Seber method (values of N_i, the population size at time i). The normal Jolly Seber method utilized marks recaptured between trips for the derivation of population estimates. This study design provided insufficient mark recoveries between trips because the trips were infrequent. This substitution of a population estimate for the Jolly Seber population size at time i, N_i, overcame the lack of sufficient mark recoveries between trips and enabled the use of the Jolly-Seber method.

The AUC method applies a straight line connection between the plotted points of the population size (y) at time of trip (x). The total escapement is estimated as the AUC divided by the average duration of time that a fish was present in the area (residence time). Residence time is calculated via a survival rate that was produced from the Jolly-Seber model.

The Jolly-Seber method yielded estimates of 10,500 and 17,000 that bracket the nearly static area-under-the-curve estimates of 13,300 and 13,200 for years 1999 and 2000 respectively. All of the estimates indicate that the spawning population is significantly increased from the two prior years and suggests an upward trend since 1997.

KEY WORDS: mark recapture, Jolly Seber, area under the curve, sockeye salmon, *Onchorhynchus nerka*, escapement estimation

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries and the United States Forest Service (USFS), Sitka Ranger District have collaborated to monitor the annual escapement of sockeye salmon to Sitkoh Lake. It is the intention of both agencies to work cooperatively in building a database to assess trends in abundance, evaluate stock status, and monitor any effect the commercial fishery and personal use/subsistence fishery may have upon the stock.

This Sitkoh Lake study is a developing model for the study of additional sockeye salmon systems as attention to these populations increases. In addition to providing results for the last two years of investigation, detail will be provided for the procedures and analysis so that this report can be an aid in the implementation of similar studies. In recent years, estimation efforts have been increased in anticipation of additional funding for investigations of this and other sockeye salmon systems. There were two trips in 1998, three in 1999, and four in 2000. In the future there may be a weir installed at this system to measure escapement independently while also conducting these estimation methods as a means of testing the technique.

Summary of Study Goals

1. Estimate the escapement of sockeye salmon to Sitkoh Lake for 1999 and 2000 using a mark-recapture study and two methods of estimation; the adapted Jolly-Seber method and the AUC method.
2. Determine the age and sex composition of sockeye salmon escapement for years 1999 and 2000.

METHODS

Logistics

Transportation to and from Sitkoh Lake was provided by the USFS via a DeHavilland Beaver on floats. The capacity was adequate for hauling three personnel with gear which included a small outboard motor, chestwaders, and an 18-gallon plastic tote, which contained a seine net. The USFS also made available the West Sitkoh Lake cabin and the accompanying 12-foot aluminum boat for use by the sampling crew. A crew of three participated on each of these sampling trips. Each trip included a two to three-hour circumnavigation of the lake performing counts and two days of beach seining the spawning grounds of the study area for mark-recapture data and age and sex data. The workload, travel time, and logistics of these trips requires a three-person crew and three days to complete with ease. The availability of the Forest Service cabin saves considerable time that would otherwise be spent setting up and taking down a campsite. The Forest Service has provided a handheld radio which permits communication with Forest Service dispatch in Sitka.

Study Procedures

The sample trips require two main tasks for estimating the population in the lake: 1) A mark-recapture study performed by use of a seine net within the study-area, and 2), a survey of the entire lake perimeter obtaining discrete sockeye salmon counts for the study-area and the non-study area.

General procedures for each trip:

1. Mark all captured sockeye salmon with an adipose clip and a secondary mark specific to a particular marking event except for fish that appear to be too weak to survive overnight or to remix with the population. Record the number of marked fish for each sampling event.
2. Determine a study area (that corresponds with the area of mark-recapture sampling) and a non-study area (the remaining lake) and conduct surveys of the lake perimeter enumerating sockeye salmon separately for each area.
3. Obtain representative age (scale), length (mid-eye to fork of tail), and sex data from a minimum of 300 to a maximum of 600 sockeye salmon, total, for all trips, throughout the mark-recapture study.

Fish Capture Procedures

Fish capture is aided by a 12-foot aluminum boat powered by a 4 horsepower outboard motor. The seine net is approximately 20-m x 2.5-m with a mesh size of 2-inch square. The seine net is piled on the bow of the boat and one end is held by a person in chestwaders standing in 1.5-m of water and 15 to 20 meters out from a shore area with concentrations of spawning sockeye salmon. The net is then deployed parallel to the shoreline about 25-m out by motoring the boat backwards and letting the net self-feed off the bow. Personnel in chestwaders then walk ends of the net towards shore encircling the salmon for sampling. The boat is then positioned next to the net and used as a sampling platform when collecting scales and sex/length data.

This study included a marking phase and a recovery phase within each trip. On most trips all of the marking phase occurred on the first day of seining and all of the recovery phase occurred on the following day. All capture efforts during marking and mark recoveries were distributed across the designated study area. The shoreline designated as our study area extended west from the gravel wash at the landing in front of the cabin to a slight point in the shoreline adjacent to the east end of the island, the end nearest to the cabin. Some trips also included an area referred to as “Clyde’s Hole” in the study area. This is a discrete area of spawning activity about 200 meters east of the landing at the cabin site. The area is included in the study area when the workload and time permits.

Fish Marking Procedures

All captured fish were marked with a clipped adipose fin. This is an easily observed sign for subsequent captures that a fish has been previously caught and needs to be inspected for other marks. A second mark was applied to distinguish the event, the first, second, third, or fourth trip. Marks used to distinguish the event included clips of the left axillary appendage, the left pelvic fin, the dorsal fin, or the anal fin. A third mark was used to indicate capture during the recovery phase, this was usually a hole punched in the left operculum.

In 1999 and 2000 all fish were marked with a clipped adipose fin, in addition, another mark was administered specific to the sampling trip (the event). All fish captured during both the marking phase and the recapture phase were given these marks. On the recovery day an additional mark was applied that served only to indicate inclusion in the recovery data, so that fish were not recounted if recaptured again in the same trip. In 1999 the recovery day mark varied, in 2000 we consistently used a left opercular punch during the mark recovery phase. This is an effective simplification of the marking regime. Note that only one mark is different from one trip to the next and that the opercular punch mark is always used on the recovery day.

As fish were marked with the appropriate fin clip they were tallied using a talley-wacker. Each sampler used two of these, one to count new fish, and one to count recaptured fish. During a recovery phase day there may be two kinds of recaptures which should be noted, those marked during the same trip and those marked from a prior trip. Recoveries from a prior trip also received the mark being used for the present trip. If they were caught during the recapture phase they also received the opercular punch like all other fish that day. It is critical to carefully record the numbers of new fish marked and the number of recoveries by type of mark for each set. A sample data recording form for the mark and recovery data collection is provided in Appendix 9. The following marking schedule is a recommended guide for 2000.

Marking schedule

1999 Trip 1 — Marking phase: (1) left axillary appendage clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) left axillary appendage clip, (3) adipose fin clip

1999 Trip 2 — Marking phase: (1) left ventral fin clip, (2) adipose fin clip
Recovery phase: (1) dorsal fin clip, (2) left ventral fin clip, (3) adipose fin clip

1999 Trip 3 — Marking phase: (1) anal fin clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) anal fin clip, (3) adipose fin clip

2000 Trip 1 — Marking phase: (1) left axillary appendage clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) left axillary appendage clip, (3)adipose fin clip

2000 Trip 2 — Marking phase: (1) left ventral fin clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) left ventral fin clip, (3)adipose fin clip

2000 Trip 3 Marking phase: (1) dorsal fin clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) dorsal fin clip, (3) adipose fin clip

2000 Trip 4 Marking phase: (1) anal fin clip, (2) adipose fin clip
Recovery phase: (1) left operculum hole-punch, (2) anal fin clip, (3) adipose fin clip

Description of Marks

All marked fish received an adipose fin clip. This was given with scissors, small pruning clippers, or a sharp knife. This mark was given to all marked fish as an easily noted indication that the fish had been previously sampled, then the fish was carefully examined for the additional marks that distinguish the event when it was marked. It was never used as the sole mark since spawners sometimes lose this fin due to spawning activity and flesh rot.

The axillary appendage is a long narrow fin-like appendage tucked in at the base of the pelvic or ventral fins. It can be snipped off at its base with scissor tips. It is reportedly beneficial to file a notch near the tip of the scissors which will catch on the fin and keep it from slipping out of the shearing action.

The ventral fin was clipped along the leading edge about one-third of its length from the fin tip. It is not necessary to clip the whole tip free. Clipping through three or four fin rays will leave a persistent and identifiable mark. This can be done with scissors or clippers.

The opercular punch was administered with a paper hole-punch tool. The hole should be placed at least one-half inch in from the margin of the opercular plate so that it persists as the edges sometimes wear or rot off during spawning. This was performed with care so that the gills were not injured.

No portion of the dorsal fin was removed. It was clipped near its base at the posterior of the fin and only three of four fin rays were cut. This is about a one-half inch long cut. The cut can be made with scissors or clippers.

The anal fin was clipped along its leading edge about one-third of the fin length from its tip. Only three or four fin rays need to be cut. The cut can be made with scissors or clippers.

Age, Sex, and Length Sampling Procedures

Three scales per fish were collected and mounted for age information. Sex and length (mid-eye to fork of tail, MEF) data were recorded for a sub-sample of the fish that were captured during the mark-recapture effort. A sample size goal of 300 to 600 fish was collected for each season. The general procedure was to obtain a certain portion of the total sample goal on each day of capturing, and from a variety of locations to obtain a sample distributed over time and area. A protocol was followed that if a net haul of salmon was going to be age-length sampled, the entire catch was sampled to reduce bias from catchability within the net caused by length/size or gender differences, body shape, kipe development, or behavior. Only new (unmarked) fish were sampled for age, sex, and length data to avoid duplication.

Lake Survey Procedures

The survey counts were conducted by motoring the boat at walking speed completely around the perimeter of the lake generally at a distance of about 15-m from the bank or as required by depth or obstacles. A count of all fish encountered on either side of the boat was attempted. Most of the lake perimeter has a sloping bottom such that it is possible to position the boat so that all the visible area is on the shore side of the boat. Certain areas have wide, shallow shores where this was not possible and in these cases, we attempted to count fish on both sides of the boat. The time during which the surveys were performed is chosen with consideration to conditions affecting visibility. Preferred conditions included calm water, little or no wind, no rain, and reasonable light levels. Separate counts were made for the study area and the non-study area. Careful and thorough notes were kept of these counts. It is valuable to note the counts of other discrete areas, that may be included as part of the study area, if time allows. It is helpful to have a map or drawing of the lake perimeter so that counts can be indicated for specific areas and landmarks can be noted. The persons performing the counts must understand that the study area is the area to be seined for the marking and recapture effort. Any area that is not covered in the marking and recapture effort cannot be considered a part of the study area. Each crew member marked an independent count and these were averaged for the analysis (Appendix 4). One person was designated as the data recorder and was responsible for carefully recording counts by date, observer, and area, in addition to noting counting conditions. Multiple counts were sometimes made of the study area because of the high density of fish in the area and the difficulty of seeing across broad shallow zones of shore area.

Population Estimation Methods

Population estimates obtained from the mark-recapture events of each trip were integral to both methods of estimating total escapement. Estimates for the sockeye salmon population in the lake were determined by two-day mark recapture studies similar to past studies (Crabtree 2000; Cook 1998). Based on the assumption that we counted the same fraction of fish actually present in both the study area and the non-study area we expanded our total count of the lake (N_v) by a ratio that we call the Petersen expansion factor P_f.

$$P_f = \frac{N_p}{n_v} \tag{1}$$

and

$$N_i = N_v \cdot P_f . \tag{2}$$

Where N_p is the population of the study area as estimated by the mark-recapture Petersen estimate and n_v is the visual count of the study area. N_i is the population estimate for the whole lake at the time of the recapture sampling and N_v is the visual count of the whole lake. Counts were given by multiple observers of the non-study area and multiple counts by multiple observers were given for the study area. The means of the multiple counts are used in the analysis (Appendix 4).

Petersen Estimates

A simple Petersen estimation formula was used (Ricker 1982):

$$\hat{N} = \frac{M \cdot C}{R}, \tag{3}$$

such that:

$\hat{N}$ = estimate of population,
M = number of marks in population,
C = total captures during mark recovery effort, and
R = recaptures that were contained in C.

The Petersen estimation method applies to a closed population. Since sockeye salmon have demonstrated strong spawning territoriality it was assumed that fish present on the marking day were the same fish present on the recovery day. Certainly immigration and to a lesser degree emigration (including mortality) occur. The immigrating fish are included in the population estimate since the estimate applies to the population at the time of mark recovery, the last phase of the trip. Note that if significant immigration is occurring that the visual count of the study area should ideally be performed on the day of recapture efforts since it is this population that generates the Petersen estimate. The emigration (including death) of marked fish would have an inflating effect on the estimate. Since spawners are very territorial and those near death are not marked the likelihood of an inflated estimate is minimized.

Escapement Estimation Methods

Jolly-Seber Method

The Jolly-Seber method is a multiple mark-recapture model that allows for an open population by estimating immigration, emigration, and mortality between sample events (Seber 1982). Given *s* sampling occasions, the method estimates M_i, the number of marked fish alive at time *i*; $ø_i$, the probability that a fish alive at time *i* is also alive at time *i+1* (i.e. the survival rate); N_i, the number of fish alive in the system at sampling occasion *i*; and B_i, the number of fish that enter the system after occasion *i* and are still alive at time *i+1*. The estimator used in this analysis includes two new parameters introduced by Schwarz et al. (1993). B_i^*, the number of animals that enter the system after occasion *i* but before occasion *i+1*, and *N*, the total number of animals that enter the system before the last sampling occasion. B_i^* (for 1<i<s-1) is estimated by:

$$\mathrm{B}_i^* = \mathrm{B}_i \frac{\log(\phi_i)}{\phi_i - 1}, \tag{4}$$

assuming recruitment and mortality is uniform between times i and $i+1$. Because B_0, B_1, and B_{s-1} are not uniquely estimable, Schwarz et al. proposes setting B_{s-1} to zero, assuming the sampling extends to the point where recruitment has virtually ended, and to estimate $\mathrm{B}_0^* + \mathrm{B}_1^*$ by,

$$\mathrm{B}_0^* + \mathrm{B}_1^* = N_2 \cdot \frac{\log(\phi)}{(\phi - 1)}, \qquad (5)$$

N is then estimated by the sum of the B_i^*.

It is recommended for this technique that there be a minimum of 10 recoveries from each prior marking period (Seber 1982). With the present study design, a trip about every two weeks, this level of recoveries is unobtainable. Therefore the method has been "hybridized" to meet the logistical limitations of working at a remote site. The estimator for Sitkoh Lake (Appendix 1) follows the framework established by Schwarz et al. but also utilized additional information provided by the two-day mark recapture events. Since frequent trips to obtain higher levels of marks is not practical, population estimates were derived from the two-day mark recapture studies that provide a reasonable substitute for population size at time i (N_i) which was then used to derive the remaining statistics in the Jolly-Seber method. These estimates were used in the estimation of the B_i, as well as M_i. Specifically we have:

$$M_i = \frac{m_i \cdot N_i}{n_i} \qquad (6)$$

$$\phi = \frac{M_{i+1}}{M_i - m_i + n_i}$$

$$\mathrm{B}_i = N_{i+1} - \phi_i \cdot N_i$$

$$N = \sum B_i^* .$$

Area Under The Curve Method

The AUC method is a technique used to convert the area under a curve into an escapement estimate (English 1992). The curve in this case, was formed by a plot of our population estimates (y) against the date of the sampling trip (x) and includes presumed start and end points of zero population. The method applied a straight line connection between the population estimates (Figure 2) and then divided the AUC by an estimate of residence time (RT) to yield an estimate for total escapement (Appendix 2).

For our purposes this residence time is the time when one-half of all of the marked fish have died after the time of marking. Since the mark-recapture data between trips yields survival rate estimates via the Jolly-Seber method, this information can be used to produce estimates of residence time by the Ben VanAlen ratio,

$$\frac{N_{i+1} - N_i}{1 - \phi} = \frac{RT}{0.5}, \text{ and so,} \qquad (7)$$

$$RT = \frac{0.5 \cdot (N_{i+1} - N_i)}{1 - \phi}. \tag{8}$$

AUC is given by:

$$\text{AUC} = 0.5 \cdot (T_i - T_{i-1}) \cdot (P_i + P_{i-1}). \tag{9}$$

T is time expressed in number of days beginning with zero at the start of the run when the population is assumed to be zero (Appendix 3). *P* is the population size.

Finally, the total escapement is given by dividing the AUC by the residence time,

$$\text{Escapement} = \frac{AUC}{RT}. \tag{10}$$

RESULTS

Population Estimates

Population estimates for the study area suggest that this area reaches a maximum population density in the last half of September. The largest estimate of 1,580 includes the Clyde's Hole area, the estimate would be 1,480 if this area were deleted. It is interesting to note that five of the seven population estimates for the study area fall within the range of 1,280 to 1,480 with the average of these being 1,410. The other smaller estimates are the earliest before the area is fully utilized as fish are still arriving. It appears that the spawning area fills to its capacity and then the population size remains relatively stable for the duration of spawning activity. Data used for the population estimates is tabulated in Appendix 7.

Total Escapement Estimate

Both estimation methods indicate that escapement for 1999 and 2000 increased markedly from the two prior years and the graph (Figure 1) shows an upward trend since 1997. Since the escapement for 1996 is estimated as over 16,000 this recent trend may be a rebound from lower than average levels or the high end of a cycle.

Estimated escapements:

Method	1999	2000
Jolly-Seber	10,400	17,000
AUC	13,300	13,200

Year	1982	1996	1997	1998
Escapement	7,200	16,300	6,000	6,600

The escapement of 7,200 for 1982 comes directly from a weir count and was not validated or adjusted by a mark recapture study. The estimate of 16,300 for 1996 was generated by a mark recapture study and displaced the weir count of 9,500 which proved to be an inadequate representation of the total escapement (Kelley and Josephson 1997). The estimates for 1997, 1998, 1999, and 2000 are not associated with any weir data and come only from mark recapture studies and counts conducted in the lake. Any sockeye salmon that may spawn in the outlet stream or in the depths of the lake where they cannot be visibly counted are not included in these estimates.

Age, Sex, and Length Distribution

The data for years 1997 through 2000 shows that sockeye salmon of age 1.3 constitute the largest component of the population ranging from 50% to 79%. The second largest age group is age-1.2 fish that range from 18% to 50%. Age 2.2s occur at levels as high as 7% but 1% to 2% is the normal range. Age 2.3s occur less frequently contributing up to 2%. Ages 0.2 and 0.3 are found infrequently.

The largest average length of 553 mm occurs with the oldest fish, age 2.3s, a very small component of the population. A close second largest average length of 551 mm occurs with the greatest age group, age 1.3s.

In comparing lengths of fish that differ in age by one-ocean-year increments it is seen that the length increases by about 270 mm for the first marine year begun as 85 mm long smolt. The second marine year of growth adds 150 mm in length, and the third adds over 50 mm. By comparing the average lengths of fish which differ in age by one freshwater year it is seen that a second year spent in freshwater adds only a few millimeters to the length.

A total of 180 sockeye salmon were sampled for age, sex, and length data in 1999 and 354 in 2000. These produced 169 (94%) and 269 (77%) ageable samples respectively (Appendix 8). One-ocean jacks have been deleted from the following percentage calculations since their capture is especially subject to selectivity depending on mesh-size and condition of the net (i.e. holes) that was used. The jacks have been a small component of the sample catch ranging from under one-half percent to 6%.

On one trip in 1998 a 2½-inch mesh (square measurement) net was used. Since it functioned as a gillnet, it allowed smaller fish to pass through. There was not a single one-ocean age (jack) captured using the 2½-inch mesh net. On the following trip, using a 2-inch square mesh net, 25 jacks were captured, 21 age 1.1s and 4 age 2.1s. Since sampling bias is known to be present for the jack-size sockeye salmon the following percentages include only the larger 2-ocean and 3-ocean age fish. Data for 1997 is included for comparison, it also has been adjusted slightly by the removal of only three jacks, 2 age 1.1s and one age

2.1. Of 1,618 sockeye salmon captured during 1997, only three were jacks suggesting that the 2½-inch square-mesh net was selecting for larger, older fish. For years 1999 and 2000 only a 2-inch mesh net was used.

Trip Descriptions

Trip 1: 1999

The marking phase occurred on September 15. The net was set 7 times during the marking phase and 603 sockeye salmon were captured, of those, 601 were marked with an adipose clip and a left axillary clip (Appendix 6). Two were not included in the marking study because they were judged to be too weak or died in the process. The recovery phase took place the following day, September 16. All fish caught during this phase were marked with a left opercular punch. Previously unmarked new fish were also given the adipose fin clip and the left axillary clip so that all marked fish from this trip had the same marking scheme. There were 7 sets made and 608 sockeye salmon were captured and examined for marks. There were 350 recovered marks and 258 new fish. A total of 859 marks were applied during this trip. On this trip 100 AWL samples were collected.

Trip 2: 1999

The marking phase occurred on the afternoon of October 4. The net was set 8 times and 719 sockeye salmon were captured (Appendix 6). Two of these were too old or weak to be included in the marking study. An adipose fin clip and a left ventral clip were applied to the 706 new fish captured. Eleven marked fish were recovered from the earlier trip. These were also given a left ventral fin clip. The recovery phase took place on October 5. The net was set nine times and 777 sockeye salmon were captured. Of these, 382 were new fish, 5 were recaptures from the first trip, and 390 were recaptures from this trip. All new fish and those marked during the marking phase were marked with a dorsal fin clip. The new fish (previously unmarked) were also given the adipose clip and the left ventral clip so that all marked fish from this trip have the same marking scheme. A total of 1,104 fish were given trip-2 marks, 1,088 were new fish, and 16 were recaptures from the prior trip. On this trip 80 AWL samples were collected.

Trip 3: 1999

The marking phase occurred on the afternoon of October 20. The net was set 10 times and captured 802 sockeye salmon of which 731 were new fish and 71 were recaptures from trip two (Appendix 6). None of these were considered too old or too weak to be included in the marking study. An adipose fin clip and an anal fin clip were applied to the 731 new fish captured. The 71 recaptured fish were given the anal fin clip. The recovery phase took place on October 21. The net was set 9 times and captured 616 sockeye salmon. Of these, 231 were new fish, 43 were recaptures from the second trip, and 342 were recaptures from this trip. All new fish were marked with a left opercular punch and the anal fin clip and adipose fin clip. The recaptured fish from the prior trip were marked with the anal fin clip and the opercular punch. A total of 1,076 fish were released with trip-3 marks, of those, 962 were new fish and 114 were recaptures from the prior trip.

Trip 1: 2000

The marking phase occurred on the afternoon of August 22 and August 23. The net was set a total of 15 times (twice on August 22) and 328 fish were captured (Appendix 6). The area referred to as Clyde's Hole was included in the study area on this trip since spawners were at lower concentrations. The fish were marked with a left axillary appendage clip in addition to the adipose fin clip. The recovery phase took place on the following day, August 24. The net was set 13 times for a catch of 315 fish, of which 112 were new and 203 were recaptures. New fish were marked the same as on the prior day and in addition were given a left opercular punch. The recaptured fish were also given an opercular punch. A total of 440 fish were given trip-1 marks. On this trip 154 AWL samples were collected.

Trip 2: 2000

The marking phase occurred on September 16. The net was set twelve times and 495 sockeye salmon were captured (Appendix 6). Seven of these were recaptures from the first trip. The new fish were marked with a left ventral fin clip and an adipose fin clip. The recaptured fish received the left ventral fin clip. The recovery phase took place on September 17. The net was set ten times and 553 sockeye salmon were captured. Of these, 360 were new fish, 5 were recaptures from the first trip, and 188 were recaptures from this trip. All of the 553 fish, new and recaptures, were marked with a left operculum punch. The new fish (previously unmarked) were also given the left ventral fin clip and the adipose fin clip. A total of 860 fish were given trip-2 marks, of those, 848 were new fish and 12 were recaptures from the prior trip. On this trip 80 AWL samples were collected.

Trip 3: 2000

The marking phase occurred on September 28. The net was set 14 times and 516 sockeye salmon were captured (Appendix 6). This included 127 recaptures from the second trip. The new fish were marked with a dorsal fin clip and an adipose fin clip. The recaptured fish also received the dorsal fin clip. The recovery phase took place on September 29. The net was set 12 times and 591 sockeye salmon were captured. Of these, 314 were new fish, 224 were recaptures from the second trip, and 180 were recaptures from this trip. All of the 591 fish, new and recaptures, were marked with a left operculum punch. The new fish (previously unmarked) were also given the dorsal fin clip and the adipose fin clip. A total of 927 fish were given trip-3 marks, of those 703 were new fish and 224 were recaptures from the prior trip. On this trip 79 AWL samples were collected.

Trip 4: 2000

The marking phase occurred on October 16. The net was set 14 times and 773 sockeye salmon were captured (Appendix 6). This included 1 recapture from the second trip and 5 recaptures from trip 3. The new fish were marked with an anal fin clip and an adipose fin clip. The recaptured fish also received the anal fin clip. Clyde's Hole was included in the study area on this trip. The recovery phase took place on October 17. The net was set 11 times and 833 sockeye salmon were captured. Of these, 423 were new fish, 7 were recaptures from the prior trip (trip 3), and 403 were recaptures from this trip. All of the 833 fish, new fish and recaptures, were marked with a left operculum punch. The new fish (previously unmarked) were also given the anal fin clip and the adipose fin clip. A total of 1,203 fish were given trip-4 marks, of those, 1,190 were new fish, 12 were recaptures from the prior trip, and 1 was a recapture from trip 2. On this trip 40 AWL samples were collected.

DISCUSSION

The escapement estimates reveal a population size that varies from 5,000 to 17,000. The population reached a low in 1997 and then steadily increased to reach high levels in 2000. Similarly high levels were observed in 1996 but dropped off precipitously the following year to the lowest level observed. A low escapement is also reported for 1982 from weir count data that is unverified by mark recapture data. The population may be exhibiting cyclic trends though the abrupt population drop from 1996 to 1997 appears erratic.

The two escapement estimation methods that were used track a similar population trend and the estimates were reasonably close. Further statistical analysis is needed to determine which method provides the tightest confidence intervals. A study comparing these estimation methods with weir data is needed to evaluate the overall accuracy of the estimates.

Both the Jolly-Seber method and the AUC method build upon a study area population estimate generated by the Petersen method. The Petersen estimation method is a point of vulnerability in this methodology. It applies to closed populations. The study area is not a closed population, we simply hope that it is “closed enough” from one day (the marking day) to the next (the recovery day) that the Petersen method can provide a viable estimate.

Observations and mark recapture data indicate that once sockeye salmon have initiated spawning activity they exhibit strong territoriality. Serial seine-netting and marking of fish along a shoreline in 60 to 80-foot increments reveals that there is surprisingly little mixing of fish from one local congregation of fish to the next, especially considering the disruption of normal movements via the netting process. This aspect of spawner behavior gives reason to believe that the population is “closed enough” to use the Petersen method. The questionable aspect of using this method therefore is not so much the active spawners, but the fish that are milling at the perimeter or within the spawning areas which may still be selecting their preferred spawning location or are tentatively preparing for active spawning. These fish may be captured and marked and then move away from the study area. This would result in the loss of marks from the study and would inflate the population estimate.

Another potential problem for the Petersen method is the disproportionate disappearance of marked fish from the population due to death or predation. The netting and handling involved in the marking process weakens, at least temporarily, spawners with already failing vitality. This factor almost certainly speeds the termination of life to an unknown degree for those fish that are captured and marked. They either expire early or are in a condition where they are easily available to predators. At Sitkoh Lake, brown bears frequent the study area and are quick to prey upon dazed or slow moving fish. The disproportionate removal or disappearance of marked fish would inflate the population estimate. To minimize this effect, fish are not included in the study if they appear too weak to survive for 24 hours. The Petersen marking and recapture is performed on two consecutive days so that there is minimal time for differential mortality to occur. The mesh size of the seine net is selected to be both effective at capture and containment but is not so large that it snares the fish tightly around the head and the operculums which can cause suffocation related stress or death.

The AUC method requires a zero population point at the start and end of the spawning curve. As the method has been applied here, these start and end points are dates determined by “best guess” estimation. There is no survey data of this specific area from which to validate or improve the placement of these points. The estimation of these points could be improved by a few drop-in surveys of the area early and late in the spawning season. However, the particular placement of these points has a relatively minor effect on the total escapement estimates since they effect only the tails of the distribution.

The Jolly-Seber method as it is applied here assumes that sampling continues until a time when recruitment has ended. Any fish that arrive after the final sample effort are not included in the estimation. Therefore timing of the final sample effort is critical so that any late arriving component of the run is not excluded from the estimation.

The design of this population estimation study includes the assumption that the counted fraction of the population will be the same for the study-area as for the non study-area. This is not necessarily a valid assumption since the physical characteristics differ greatly between the two areas. Also the concentration of fish differs greatly between the two areas which could effect the accuracy of visual counting. It has been demonstrated that the error from undercounting increases as the numbers being counted increases (Jones, et al. 1998). The distribution of sockeye salmon between the study area and the non-study area remained remarkably consistent for each of the sampling trips. The study-area, which constitutes roughly 5% of the shoreline, contained 60% or more of the visually counted salmon. The study area features wide, shallow, gravel bottomed zones with high concentrations of sockeye salmon. There are also cut banks at some of the sample locations that conceal spawning activity underneath. The study area appears to be the prime location for concentrated spawning activity. Some of the densely populated spawning areas were too shallow to allow the boat to motor any closer to shore than about 40 meters. Salmon were scattered out this distance and beyond. The boat must pass through the loosely congregated salmon and this causes some amount of scattering and darting back and forth. In these situations it is difficult to say if all fish get counted, or to say that fish are not counted twice on occasion.

The non study-area is roughly 95% of the lakeshore and it generally has very different physical characteristics and a much lower density of sockeye salmon than the designated study area. These qualities likely effect the counted fraction of the sockeye salmon present there. Much of the shoreline in the non study-area has a bottom that descends rapidly to a depth beyond visibility. The bottom is littered with logs, woody debris, and occasional growths of aquatic vegetation. In most areas the boat can be maneuvered 20 meters or less out and parallel to shore and all visible lake bottom is in view on one side of the boat. When salmon are encountered they are usually in very small numbers and are easily counted without confusion. There are some wide shallow areas at the east end of the lake where the bottom is made up of mud and silt and no salmon were observed there. An area named “Clyde's Hole” on the north shoreline (areas 12 and 13 from the 1997 study) is the same type of habitat as the study area and is located along the shoreline a few hundred yards east of the edge of our established study area. It is an area that is easily seined and sampled and harbors good concentrations of spawners. It is included in the study area when the workload (depending on number of fish, number of personnel, and amount of time) permits.

At some locations we observe spawning activity to a depth of about seven meters. Depending on the conditions of visibility this is near the limit of visual observation. It is possible that a component of the escapement utilizes deep-water spawning areas that are beyond the range of observation, if so, these are not being included in the population estimate by these methods. One means of addressing this issue would be by the use of radio tags. A weir or some other means of capturing fish arriving at the lake would permit radio tagging of a fraction of the fish entering the lake to identify spawning area distributions and to help determine if a significant portion of the spawning population remains invisible to observation.

Conclusions

The goal of this study is to investigate escapement estimation methods that provide a useful index of the escapement population. The index is intended to have more significance than as a simple trend indicator of spawner abundance, it is also meant to give an approximation of the actual size of the population. Greater effort and cost in the form of either mark recapture studies or weir installations is required to assess the actual population size of the escapement. A balance is sought in the cost versus benefit of increased accuracy in escapement estimation. Survey counts at prescribed dates would be sufficient data as strictly an index of population trends. Since the visual counts treated with the AUC method track well with the more intensive mark-recapture efforts cost savings might be achieved with an acceptable loss of estimation accuracy by substituting survey count trips for expensive mark-recapture trips. The survey counts could be treated with the same expansion factors that are determined by one or two mark-recapture trips or by average values derived from new and old data.

It is shown that the AUC method when used with only the lake count data provides obvious correspondence with total population estimates made using the AUC method with all the mark recapture data. This shows that the counts themselves are a credible *index* of run strength but give no total escapement estimate without other information. The mark recapture efforts serve to relate the counts to the total number of fish present in the system. The relationship between counts and total estimates may offer sufficient predictability to either eliminate or reduce mark-recapture efforts. The operation of a weir combined with these mark-recapture studies would be a means to calibrate the estimation methods and to further evaluate the relationship between visual counts and these estimation methods.

Future Investigations

As interest increases in Southeast Alaska sockeye salmon stocks, it is important that a systematic means of indexing escapement levels be established. If methods presented here are considered for use more broadly it would be imperative to apply an intensive effort at Sitkoh Lake to evaluate the efficacy of these methods. Ideally weir data in conjunction with the same independent mark-recapture study as described in this report would serve to evaluate the reliability of these methods by producing separate estimates for the population via each technique. Marking at the weir could include individual identifiers that may aid in determining residence time on the spawning grounds empirically. These could be compared to estimates as derived in this report. A weir could be situated at the outlet of the lake to provide ready access for frequent spawning area surveys and mark-recapture activities. The outlet stream could be walked and inspected for sockeye salmon spawning activity periodically. Radio tagging could be included in the study to document spawning area distribution and evaluate the significance of any deep-water spawning population component. A thorough investigation would produce information valuable for the re-evaluation of previous studies and would improve the ability to make sound estimates in the future.

Further effort is needed to address some or all of the following issues:

1. Assess the accuracy of escapement estimates acquired by the mark recapture study design as executed in 1997 through 2000. This could be accomplished by installing a weir where a distinguishing mark is applied to create another mark recapture data set for a separate escapement estimate.
2. Statistically evaluate the escapement estimation methods, the Jolly-Seber method, and the AUC method to determine the confidence boundaries provided by each.
3. Estimate the residence time of sockeye salmon on the spawning grounds and improve our knowledge on the population zero points, the start and end dates of spawning activity at Sitkoh Lake.
4. Determine if there is a population of deep water spawners in the lake that are not available for visual surveys or mark-recapture studies, possibly by radio tagging, and estimate the population fraction.
5. Determine any outlet stream population segment that may be unrecognized by present studies and estimate the population fraction.

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Table 1. Sitkoh Lake escapement estimates summary.

Year	Estimated Escapement	
1982	7,200	Weir count
1996	16,300	Mark-recapture (weir count of 9,500 was inaccurate)
1997	6,000	Adapted Jolly-Seber Method
	4,900	Area Under the Curve
1998	6,600	No Jolly-Seber available, only two point estimates
1999	10,500	Adapted Jolly-Seber Method
	13,300	Area Under the Curve
2000	17,000	Adapted Jolly-Seber Method
	13,200	Area Under the Curve

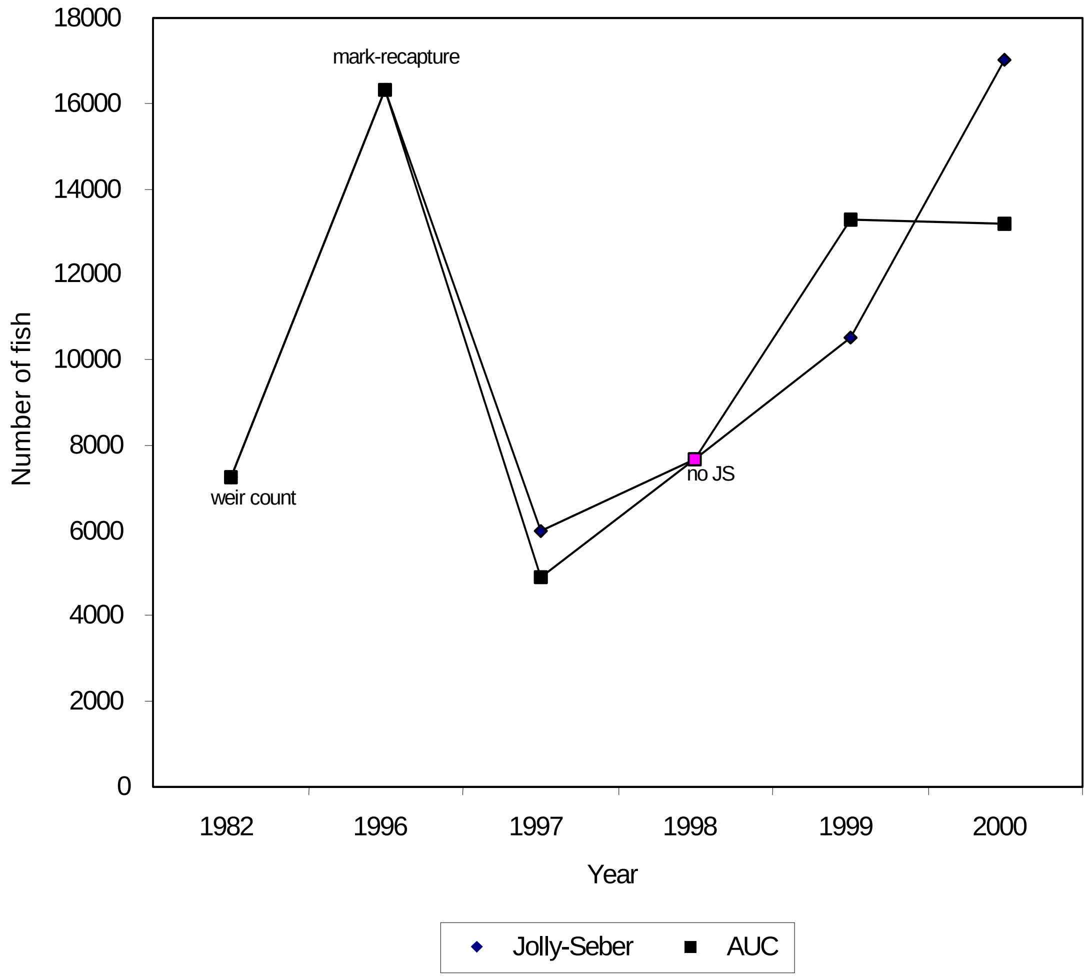

Figure 1. Sitkoh Lake sockeye salmon escapement estimates.

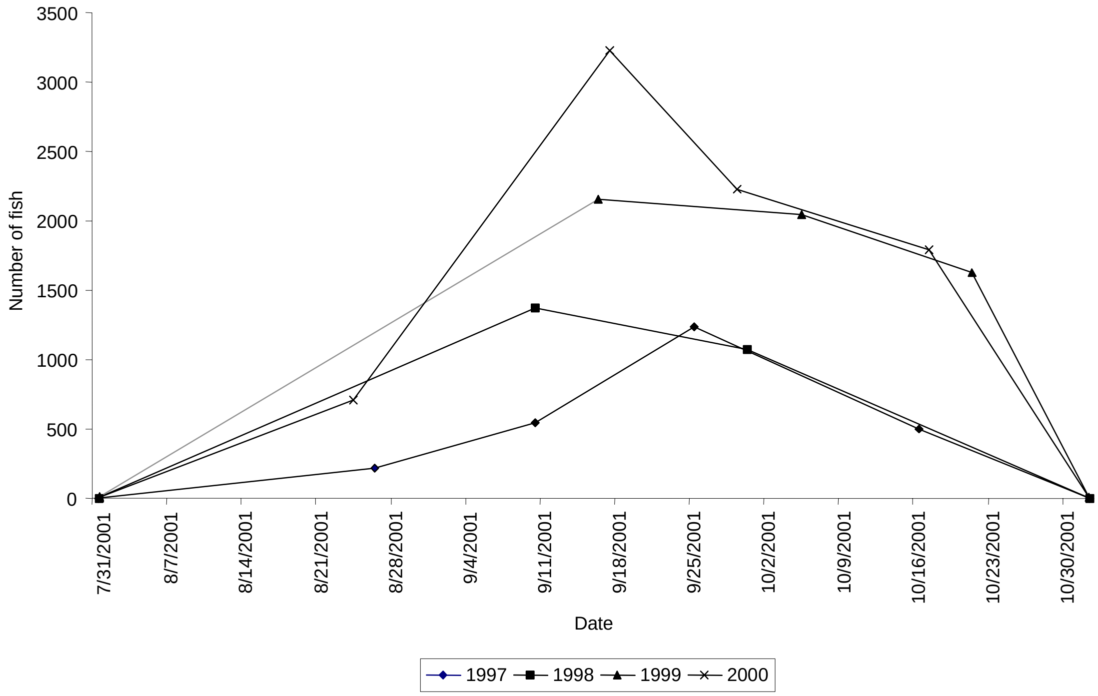

Figure 2. Population estimates for Sitkoh Lake sockeye salmon.

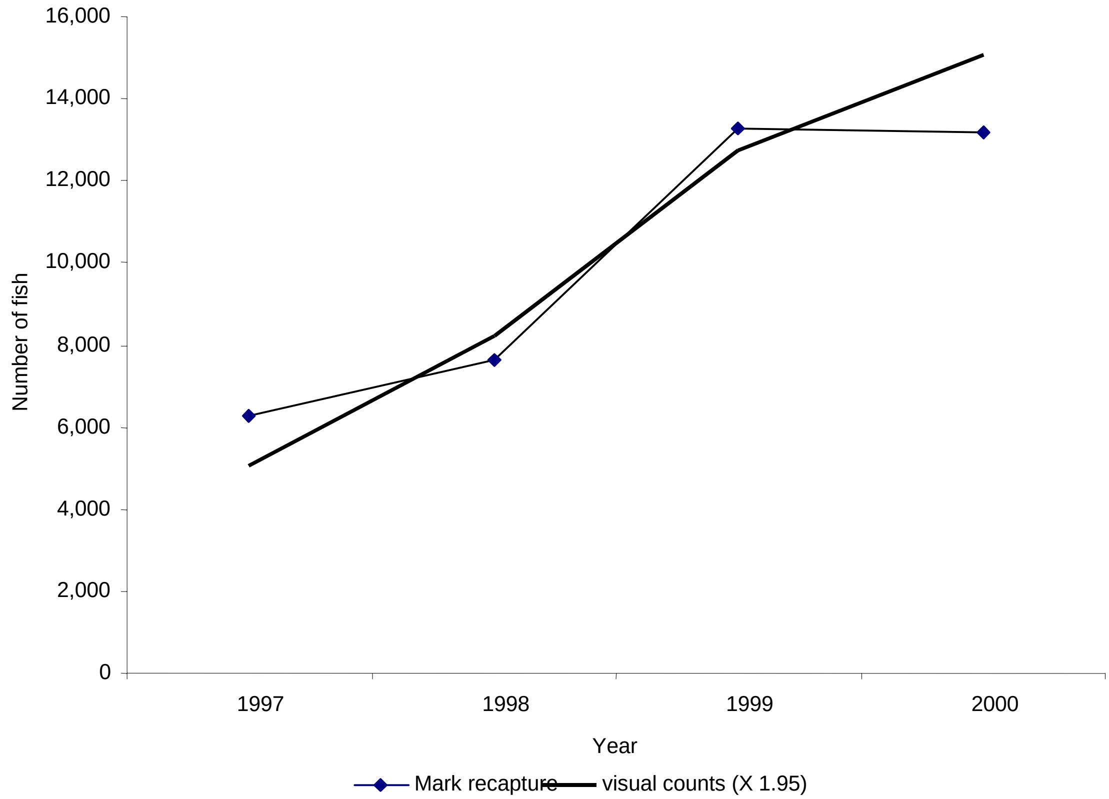

Figure 3. AUC estimates from mark-recapture versus visual counts.

APPENDICES

Appendix 1.a. Jolly-Seber (Blick adaptation) escapement estimation for Sitkoh Lake 1999.

Trip	Dates	Number Captured (n_i)	Number of Marks Released	No. of Recaptures by Trip When Marked 1	2	3	Total Recaptures (m_i)
1	9/15-16	859	859				0
2	10/4-5	1,104	1,104	16			16
3	10/20-21	1,076	1,076	0	114		114
				16	114	0	

Jolly-Seber method, modified by inserting Petersen population estimates for values of N_i.

Time *i*	n_i	*mi*	*Ni*	*Mi*	*fi*	*Bi*	*B*i*
1	859	0	1,044	0	0.024	1,403	5,452
2	1,104	16	1,428	21	0.138	1,248	2,866
3	1,076	114	1,445	153	0.000	0	
					Escapement Estimate =		8,318

Expansion for the Whole Lake Population:

time *i*	Lf*n_i	Lf*m_i	Lf*N_i	M_i	Copied From Above f_i	B_i	$B*_i$	Lake Fraction Expansion Factors *Lf*
1	1,769.54	0	2,151	0	0.024	1,876	7,360	2.06
2	1,490.4	21.6	1,928	28	0.138	1,367	3,139	1.35
3	1,216	129	1,633	173	0.000	0		1.13
				Escapement Estimate (Expanded) =			10,499	

n_i = number of fish captured in the ith sample, i = 1,…,s

m_i = number of marked fish captured in the ith sample, i = 1,…,s

N_i = number of fish alive in the study area at sampling occasion i, i.e., the abundance. In this application it is the instantaneous Petersen estimate. i = 1,…,s

M_i = number of marked fish alive in the study area at sampling occasion i, i = 1,…,s estimated by m_iN_i/n_i

f = probability that a fish at sampling occasion i will be alive at sampling occasion i + 1 estimated by $M_{i+1}/(M_i-m_i+n_i)$

B_i = number of fish that enter the area after sampling occasion i and are still alive at sampling occasion i + 1. Given by, $Bi = Ni+1-fiNi$

$B*_i$ = number of fish that enter area after sampling occasion i but before sampling occasion i + 1.

$B*_i{}^3$ B_i because it includes those fish that enter after sampling occasion i but die before sampling occasion *i* + 1. Given by, $Bi* = Bi\ Log(fi)/(fi-1)$

Lf (lake fraction) is an expansion factor that relates study-area population to whole lake population by ratio of visual counts.

Lf = count of whole lake/count of study area only.

Appendix 1.b. Jolly-Seber (Blick adaptation) escapement estimation for Sitkoh Lake 2000.

Trip	Dates	Number Captured (n_i)	Number of Marks Released	No. of Recaptures by Trip When Marked 1	2	3	4	Total Recaptures (m_i)
1	8/22-24	440	440					0
2	9/15-17	860	848	12				12
3	9/27-29	927	703	0	224			224
4	10/16-18	1,203	1,190	0	1	12		13
				12	225	12		

Jolly-Seber method, modified by inserting Petersen population estimates for values of N_i.

Time i	n_i	m_i	N_i	M_i	f_i	B_i	B_{*i}
1	440	0	509	0	0.046	1,412	4,645
2	860	12	1,435	20	0.355	767	1,231
3	927	224	1,277	309	0.017	1,563	6,486
4	1,203	13	1,585	17	0.000	0	

Escapement Estimate = 12,362

Expansion for the Whole Lake Population:

time i	Lf*n_i	Lf*m_i	Lf*N_i	M_i	Copied From Above f_i	B_i	B_{*i}	Lake Fraction Expansion Factors Lf
1	616	0	713	0	0.046	2,292	7,526	1.40
2	1,393.2	19.44	2,325	32	0.355	1,396	2,240	1.62
3	1,613	390	2,222	537	0.017	1,753	7,275	1.74
4	1,359	15	1,791	19	0.000	0		1.13

Escapement Estimate (Expanded) = 17,040

n_i = number of fish captured in the ith sample, i = 1,…,s

m_i = number of marked fish captured in the ith sample, i = 1,…,s

N_i = number of fish alive in the study area at sampling occasion i, i.e., the abundance. In this application it is the instantaneous Petersen estimate. i = 1,…,s

M_i = number of marked fish alive in the study area at sampling occasion i, i = 1,…,s estimated by m_iN_i/n_i

f = probability that a fish at sampling occasion i will be alive at sampling occasion i + 1 estimated by $M_{i+1}/(M_i\text{-}m_i+n_i)$

B_i = number of fish that enter the area after sampling occasion i and are still alive at sampling occasion i + 1. Given by, $B_i = N_{i+1} - f_i N_i$

$B*_i$ = number of fish that enter area after sampling occasion i but before sampling occasion i + 1.

$B*_i{}^3\ B_i$ because it includes those fish that enter after sampling occasion i but die before sampling occasion i + 1. Given by, $B_i* = B_i \mathrm{Log}(f_i)/(f_i\text{-}1)$

Lf (lake fraction) is an expansion factor that relates study-area population to whole lake population by ratio of visual counts.

Lf = count of whole lake/count of study area only.

Appendix 2.a. AUC escapement estimation, 1999.

Sitkoh Lake 1999			
	Trip 1	Trip 2	Trip 3
Dates (day of recapture effort)	16-Sep	5-Oct	21-Oct
Number of marks in population (*M*)	601	717	802
Number of population examined for marks(*C*)	608	777	616
Number of "C" with marks (*R*)	350	390	342
Petersen estimate of study area (*Np = MC/R*)	1,044	1,428	1,445
Visual survey of total lake (*Nv*)	1,083	1,031	493
Visual survey of study area (*nv*)	525	720	437
Visual survey of non-study area	558	311	56
Percent of population inside study area	48.5	69.8	88.6
Petersen expansion factor (*Pf = Np/nv*)	1.99	1.98	3.31
Lake fraction expansion factor (*Lf = Nv/nv*)	2.06	1.43	1.13
Point estimate for lake population (*Pf*Nv*)	2,154	2,046	1,630

Area Under the Curve

Year 1999		P_i				
	T_i	Point				
Trip	Days	Estimate	RT	AUC	AUC/RT	
0		0			0	
1	45.71	2,154	9.8	20,527.6	5,023	
2	19.06	2,046	9.8	33,663.0	4,084	
3	16.03	1,630	9.3	20,585.6	3,168	
X	11.2	0	9.3		982	
					13,257	= Escapement estimate

Where:

AUC = 0.5*(T_i-T_{i-1})*(P_i+P_{i-1})

Escapement = AUC/RT

The data does not provide information for estimating RT for trip 1 or X so RTs estimated from adjacent trips are used.

Appendix 2.b. AUC escapement estimation, 2000.

Sitkoh Lake 2000	Trip 1	Trip 2	Trip 3	Trip 4
Dates (day of recapture effort)	24-Aug	17-Sep	29-Sep	17-Oct
Number of marks in population (*M*)	328	488	389	767
Number of population examined for marks(*C*)	315	553	591	833
Number of "C" with marks (*R*)	203	188	180	403
Petersen estimate of study area (*Np = MC/R*)	509	1,435	1,277	1,585
Visual survey of total lake (*Nv*)	386	967	1,762	980
Visual survey of study area (*nv*)	276	430	1,010	868
Visual survey of non-study area	110	537	752	112
Percent of population inside study area	71.5	44.5	57.3	88.6
Petersen expansion factor (*Pf = Np/nv*)	1.84	3.34	1.26	1.83
Lake fraction expansion factor (*Lf = Nv/nv*)	1.40	2.25	1.74	1.13
Point estimate for lake population (*Pf*Nv*)	712	3,228	2,228	1,790

Area Under the Curve

Year 2000 Trip	T_i Days	P_i Point Estimate	RT	AUC	AUC/RT	
0		0			0	
1	22.63	712	12.7	8056.3	634	
2	24.23	3,228	12.7	47,733.1	3,759	
3	12.01	2,228	9.3	32,763.3	3,523	
4	18.24	1,790	9.3	36,644.2	3,940	
X	14	0	9.3	12,530.0	1,347	
					13,203	= Escapement estimate

Where,

AUC = $0.5*(T_i-T_{i-1})*(P_i+P_{i-1})$

Escapement = AUC/RT

The data does not provide information for estimating RT for trip 1 or X so RTs estimated from adjacent trips are used.

RTs for trips 3 and 4 were calculated independently but yielded identical results.

Appendix 3.a. Worksheet for AUC data, 1999. The number of days between sampling trips are calculated by weighting marking days and recovery days by number of fish marked and recovered. August 1 and November 1 are assumed to have zero population as a start and end point.

Midpoint (mp) occurs on day with value 0<mp<1, select end or start of time period.

Sitkoh Lake 1999

		MIDPOINT				MIDPOINT	
Trip 1	Number	Day Fraction		Trip 2	Number	Day Fraction	
Date	**Marked**	End	Start	Date	**Marked**	End	Start
15-Sep	601	0.71	0.29	4-Oct	717	0.77	0.23
16-Sep	258	-0.66	1.66	5-Oct	387	-0.43	1.43
		0.00	0.00			0.00	0.00
	859				1104		
Midpoint	429.5			Midpoint	552		

		MIDPOINT	
Trip 3	Number	Day Fraction	
Date	**Marked**	End	Start
20-Oct	802	0.67	0.33
21-Oct	274	-0.96	1.96
		0.00	0.00
	1076		
Midpoint	538		

		MIDPOINT				MIDPOINT	
Trip 1	Number	Day Fraction		Trip 2	Number	Day Fraction	
Date	**Recovered**	End	Start	Date	**Recovered**	End	Start
15-Sep	0	0.00	0.00	4-Oct	11	0.73	0.27
16-Sep	0	0.00	0.00	5-Oct	5	-0.60	1.60
						0.00	0.00
	0				16		
Midpoint	0			Midpoint	8		

		MIDPOINT	
Trip 3	Number	Day Fraction	
Date	**Recovered**	End	Start
20-Oct	71	0.80	0.20
21-Oct	43	-0.33	1.33
		0.00	0.00
	114		
Midpoint	57		

Number Of Days Weighted By Number Of Samples Per Day:

		Fractional Days			
	Whole Days	Start	End	Total	
Period 0	45		0.71	45.71	0 Fish To Trip 1
Period 1	18	0.29	0.77	19.06	Trip 1 To 2
Period 2	15	0.23	0.8	16.03	Trip 2 To 3
Period 3	11	0.2	0	11.2	Trip 3 To 0 Fish

	Residence Time (RT) Calculations				(.5)*Days/Dr
		Days	Survival	Death(Dr)	RT (Days)
Period 1	Trip 1 To 2	19.06	0.024	0.976	9.8
Period 2	Trip 2 To 3	16.03	0.138	0.862	9.3

Appendix 3.b. Worksheet for AUC data, 2000. The number of days between sampling trips are calculated by weighting marking days and recovery days by number of fish marked and recovered. August 1 and November 1 are assumed to have zero population as a start and end point.

Midpoint (mp) occurs on day with value 0<mp<1, select end or start of time period.

Sitkoh Lake 2000

		MIDPOINT				MIDPOINT	
Trip 1	Number	Day Fraction		Trip 2	Number	Day Fraction	
Date	**Marked**	End	Start	Date	**Marked**	End	Start
22-Aug	37	0.00	0.00	16-Sep	495	0.87	0.13
23-Aug	291	0.63	0.37	17-Sep	365	-0.18	1.18
24-Aug	112	-0.96	1.96		0	0.00	0.00
	440				860		
Midpoint	220			Midpoint	430		

		MIDPOINT				MIDPOINT	
Trip 3	Number	Day Fraction		Trip 4	Number	Day Fraction	
Date	**Marked**	End	Start	Date	**Marked**	End	Start
28-Sep	516	0.90	0.10	16-Oct	773	0.78	0.22
29-Sep	411	-0.13	1.13	17-Oct	430	-0.40	1.40
	0	0.00	0.00		0	0.00	0.00
	927				1203		
Midpoint	463.5			Midpoint	601.5		

		MIDPOINT				MIDPOINT	
Trip 1	Number	Day Fraction		Trip 2	Number	Day Fraction	
Date	**Recovered**	End	Start	Date	**Recovered**	End	Start
22-Aug	0	0.00	0.00	16-Sep	7	0.86	0.14
23-Aug	0	0.00	0.00	17-Sep	5	-0.20	1.20
24-Aug	0	0.00	0.00		0	0.00	0.00
	0				12		
Midpoint	0			Midpoint	6		

		MIDPOINT				MIDPOINT	
Trip 3	Number	Day Fraction		Trip 4	Number	Day Fraction	
Date	**Recovered**	End	Start	Date	**Recovered**	End	Start
28-Sep	127	0.88	0.12	16-Oct	5	0.00	0.00
29-Sep	97	-0.15	1.15	17-Oct	7	0.14	0.86
	0	0.00	0.00		0	0.00	0.00
	224				12		
Midpoint	112			Midpoint	6		

Number Of Days Weighted By Number Of Samples Per Day:

		Fractional Days			
	Whole Days	Start	End	Total	
Period 0	22		0.63	22.63	0 Fish To Trip 1
Period 1	23	0.37	0.86	24.23	Trip 1 To 2
Period 2	11	0.13	0.88	12.01	Trip 2 To 3
Period 3	18	0.1	0.14	18.24	Trip 3 To 4
Period 4	14	0.86		14.86	Trip 4 To 0 Fish

	Residence Time (RT) Calculations				(.5)*Days/Dr
		Days	Survival	Death(Dr)	RT (Days)
Period 1	Trip 1 To 2	24.23	0.046	0.954	12.7
Period 2	Trip 2 To 3	12.01	0.355	0.645	9.3
Period 3	Trip 3 To 4	18.24	0.017	0.983	9.3

Appendix 4.a. Visual survey summary, 1999. This worksheet provides an average count of the study-area population for calculating the Petersen expansion factor (Pf) used to expand the whole lake count. It also yields the lake factor (Lf) which is used to expand the Jolly-Seber estimate of the study-area to the whole lake.

Sitkoh Lake 1999

Trip 1 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	
RB	493	259	325	1,077	Clyde's Hole is not included in the study	
KC	559	237	331	1,127	area this trip	
MV	524	215	306	1,045		
						Lf Factor
Average	525.3	237.0	320.7	1,083.0		2.06
Median	526	248	328	1,102		2.10

Trip 2 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	
CA	570	330	30	930	Clyde's Hole is not	
	760	260		1020	included in the study	
MO	665	80	33	778	area this trip	
	812	118		930		
BW	690	240	140	1070		
	820	280		1100		
						Lf Factor
Average	719.5	218.0	67.7	971.3		1.35
Median	725	250	33	975		1.34

Trip 3 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	
CA	520	50	1	571	Clyde's Hole is not	
MO	320	54	1	375	included in the study	
BW	470	60	1	531	area this trip	
						Lf Factor
Average	436.7	54.7	1.0	492.3		1.13
Median	470	54	1	531		1.13

Appendix 4.b. Visual survey summary, 2000. This worksheet provides an average count of the study-area population for calculating the Petersen expansion factor (Pf) used to expand the whole lake count. It also yields the lake factor (Lf) which is used to expand the Jolly-Seber estimate of the study-area to the whole lake.

Sitkoh Lake 2000

Trip 1 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	Lf Factor
BVA	165	41	79	285	Clyde's Hole is included in the study area this trip	
KC	259	58	121	438		
RB	243	61	130	434		
Average	222.3	53.3	110.0	385.7		1.40
Median	243	58	121	434		1.44

Trip 2 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	Lf Factor
MV	398	184	370	952	Clyde's Hole is not included in the study area this trip	
RB	510	168	351	1029		
TW	382	151	386	919		
Average	430.0	167.7	369.0	966.7		1.62
Median	398	168	370	952		1.68

Trip 3 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	Lf Factor
RB	1080	229	542	1851	Clyde's Hole is not included in the study area this trip	
DG	940	217	515	1672		
Average	1010.0	223.0	528.5	1761.5		1.74
Median	1010	223	528.5	1761.5		1.74

Trip 4 Observer	Study Area	Clyde's Hole	Non-study Area	Total Lake	Comment	Lf Factor
CA	770	60	101	931	Clyde's Hole is included in the study area this trip	
MO	1020	70	138	1228		
BW	620	65	96	781		
Average	803.3	65.0	111.7	980.0		1.13
Median	770	65	101	931		1.11

Appendix 5. AUC calculations for visual counts.

(July 31 and Nov. 1 are zero population.)

Year	Counts Date	SA	Non SA	All lake
1997	25-Sep	422	128	550
	16-Oct	94	31	125
1998	8-Sep	388	297	685
	28-Sep	380	286	666
1999	15-Sep	525	558	1,083
	4-Oct	720	286	971
	20-Oct	437	56	492
2000	22-Aug	222	163	386
	16-Sep	430	537	967
	28-Sep	1,010	752	1,762
	16-Oct	803	177	980

AUC calculations for visual all-lake counts.

Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
1997	56	0	550	0	15,400	2,603	9
	77	56	125	550	7,088	2,343	10
	92	77	0	125	9,38	2,130	11
					23,425		
Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
1998	39	0	685	0	13,358	4,206	9
	59	39	666	685	13,510	3,786	10
	92	59	0	666	10,989	3,442	11
					37,857		
Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
1999	46	0	1,083	0	24,909	6,537	9
	65	46	971	1,083	19,513	5,883	10
	81	65	492	971	11,704	5,348	11
	92	81	0	492	2,706		
					58,832		
Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
2000	22	0	386	0	4,246	7,729	9
	47	22	967	386	16,913	6,956	10
	59	47	1,762	967	16,374	6,324	11
	77	59	980	1,762	24,678		
	92	77	0	980	7,350		
					69,561		

	Counts RT 9	Esc. estimate.	Counts X 2	Expansion calculations
1997	2,603	6,276	5,075.85	2.41
1998	4,206	7,659	8,201.7	1.82
1999	6,537	13,257	12,747.15	2.03
1900	7,729	13,203	15,071.55	1.71

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AUC for point estimates year 1998.

Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
1998	39	0	1,371	0	26,734.5	7,659	9
	59	39	1,075	1,371	24,460	3,786	10
	92	59	0	1,075	17,737.5	3,442	11
					68,932		

Used RT of 9. Expansion of 1.95 was used.

AUC for 1998 is straight line between points here, AUC in 1998 report was of a normal curve fitted to two points of escapement estimates.

Year	*Ti*	*Ti-1*	*Pi*	*Pi-1*	AUC	Escapement	RT
1997	56	0	1,232	0	34,496	6,276	9
	77	56	503	1,232	18,217.5	5,649	10
	92	77	0	503	3,772.5	5,135	11
					56,486		

1997 is calculated by the only two dates that have corresponding lake counts for these escapement estimates.

Study Area estimate	Expansion Factor	Lake Estimate
924	1.33	1,232
377	1.33	503

AUC is calculated above for 1998 by straight line method since the AUC in the 1998 report was for a normal curve fitted to the two point estimates.

Appendix 6. Data for the Petersen estimates.

1999	**Trip #1**	**Trip #2**	**Trip #3**
Dates (day of recapture effort)	9/16	10/5	10/21
Number of marks in the population (*M*)	601	717	802
Number of population examined for marks (*C*)	608	777	616
Number of "C" with marks (*R*)	350	390	342
Estimated population of study area (*Np*)	1,044	1,428	1,445
Visual survey total lake (*Nv*)	1,083	1,031	493
Visual survey of study area (*nv*)	525	720	437
Visual survey of non study area	558	311	56
Percent of population inside study area	48.5	69.8	88.6
Petersen expansion factor (*Pf=Np/nv*):	1.99	1.98	3.31
Point estimate for lake population (*Pf* * *Nv*)	2,154	2,046	1,630

2000	**Trip #1**	**Trip #2**	**Trip #3**	**Trip #4**
Dates (day of recapture effort)	8/24	9/17	9/29	10/17
Number of marks in the population (*M)*	328	488	389	767
Number of population examined for marks (*C*)	315	553	591	833
Number of "C" with marks (*R*)	203	188	180	403
Estimated population of study area (*Np*)	509	1,435	1,277	1,585
Visual survey total lake (*Nv*)	386	967	1,762	980
Visual survey of study area (*nv*)	276	430	1,010	868
Visual survey of non study area	110	537	752	112
Percent of population inside study area	71.5	44.5	57.3	88.6
Petersen expansion factor (*Pf=Np/nv*):	1.84	3.34	1.26	1.83
Point estimate for lake population (*Pf* * *Nv*)	712	3,228	2,228	1,790

Appendix 7. Sitkoh Lake mark recapture data, 2000.

Trip 1
Marking Phase

Date	Time	Set #	New Fish (Given Marks)	Location
22-Aug		1	19	left of Clyde's Hole
22-Aug		2	18	Clyde's Hole and E. end of study area
23-Aug		3	48	SA[a]
23-Aug		4	25	SA
23-Aug		5	15	SA
23-Aug		6	9	SA
23-Aug		7	84	SA
23-Aug		8	54	SA
23-Aug		9	15	SA
23-Aug		10	6	SA
23-Aug		11	3	SA
23-Aug		12	2	SA
23-Aug		13	6	just W. of Clyde's Hole
23-Aug		14	11	Clyde's hole
23-Aug		15	13	Clyde's hole
Totals:			328	

Trip 1
Recovery Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From This Trip	Total Catch	Location
24-Aug	10:00	1	22	14	36	west end
24-Aug	10:20	2	14	5	19	SA
24-Aug	10:42	3	12	34	46	SA
24-Aug	11:07	4	18	35	53	SA
24-Aug	11:25	5	4	15	19	SA
24-Aug		6	19	33	52	SA
24-Aug	14:20	7	3	8	11	SA
24-Aug	14:35	8	7	7	14	SA
24-Aug	14:50	9	3	4	7	SA
24-Aug	15:05	10	0	6	6	SA
24-Aug	15:15	11	1	10	11	SA
24-Aug		12	3	9	12	SA
24-Aug	15:35	13	6	23	29	SA
Totals:			112	203	315	
Total trip one marks:			440			

[a] Indicates study area.

-continued-

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Trip 2
Marking Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Total Catch	Location
16-Sep	10:00	1	18	0	18	east
16-Sep	11:00	2	12	0	12	SA
16-Sep	11:40	3	22	0	22	SA
16-Sep	12:15	4	24	0	24	SA
16-Sep	13:00	5	29	1	30	SA
16-Sep	13:30	6	35	2	37	SA
16-Sep	14:00	7	48	0	48	SA
16-Sep	14:40	8	72	0	72	SA
16-Sep	15:30	9	81	2	83	SA
16-Sep		10	68	2	70	SA
16-Sep		11	32	0	32	SA
16-Sep	18:30	12	47	0	47	west
Totals:			488	7	495	

Trip 2
Recapture Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Recaptures From This Trip	Total Catch
17-Sep	9:07	1	17	0	0	17
17-Sep	9:26	2	27	1	20	48
17-Sep	9:55	3	26	0	5	31
17-Sep	10:26	4	58	0	48	106
17-Sep	11:15	5	68	0	22	90
17-Sep	12:00	6	76	3	41	120
17-Sep	13:00	7	32	0	18	50
17-Sep	13:25	8	43	0	23	66
17-Sep	13:55	9	5	1	10	16
17-Sep	14:15	10	8	0	1	9
Totals:			360	5	188	553
Total trip two marks:			848			
Recovered trip one marks:				12		
Fish examined for previous trip marks:						

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Trip 3
Marking Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Recaptures From Second Trip	Total Catch
28-Sep	9:45	1	26	0	3	29
28-Sep	10:15	2	25	0	10	35
28-Sep		3	16	0	4	20
28-Sep		4	56	0	21	77
28-Sep	12:45	5	84	0	26	110
28-Sep	14:45	6	4	0	4	8
28-Sep		7	2	0	2	4
28-Sep		8	28	0	5	33
28-Sep		9	5	0	0	5
28-Sep		10	15	0	2	17
28-Sep		11	28	0	3	31
28-Sep		12	8	0	7	15
28-Sep		13	38	0	19	57
28-Sep	16:00	14	54	0	21	75
Totals:			389	0	127	516

Trip 3
Recapture Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Recaptures From Second Trip	Recaptures From This Trip
29-Sep	9:30	1	2	0	0	3
29-Sep		2	44	0	2	6
29-Sep	10:10	3	63	0	12	18
29-Sep	11:00	4	25	0	7	13
29-Sep	11:30	5	56	0	23	34
29-Sep	12:00	6	66	0	23	39
29-Sep	12:30	7	6	0	2	2
29-Sep	12:45	8	8	0	7	10
29-Sep	13:00	9	16	0	8	23
29-Sep	13:15	10	11	0	6	11
29-Sep	13:50	11	13	0	6	12
29-Sep	14:00	12	4	0	1	9
Totals:			314	0	97	180
Total trip three marks:			703			
Recovered trip one marks:				0		
Recovered trip two marks:					224	
Fish examined for previous trip marks:						

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Trip 4
Marking Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Recaptures From Second Trip	Recaptures From Third Trip
16-Oct	9:46	1	5	0	0	0
16-Oct	10:03	2	31	0	0	0
16-Oct	10:47	3	116	0	0	0
16-Oct	11:37	4	110	0	0	2
16-Oct	13:30	5	138	0	1	1
16-Oct	14:20	6	87	0	0	0
16-Oct	14:43	7	82	0	0	1
16-Oct	15:00	8	50	0	0	1
16-Oct	15:33	9	12	0	0	0
16-Oct	15:40	10	21	0	0	0
16-Oct	15:52	11	20	0	0	0
16-Oct	16:04	12	28	0	0	0
16-Oct	16:15	13	18	0	0	0
16-Oct	16:30	14	49	0	0	0
Totals:			767	0	1	5

Trip 4
Recapture Phase

Date	Time	Set #	New Fish (Given Marks)	Recaptures From First Trip	Recaptures From Second Trip	Recaptures From Third Trip
17-Oct	9:58	1	20	0	0	0
17-Oct	10:18	2	81	0	0	2
17-Oct	10:57	3	61	0	0	0
17-Oct	11:31	4	61	0	0	2
17-Oct	12:06	5	80	0	0	0
17-Oct	13:56	6	33	0	0	2
17-Oct	14:21	7	8	0	0	0
17-Oct	14:32	8	16	0	0	1
17-Oct	14:45	9	12	0	0	0
17-Oct	14:57	10	13	0	0	0
17-Oct	15:14	11	38	0	0	0
Totals:			423	0	0	7

Total trip four marks:	1190			
Recovered trip one marks:		0		
Recovered trip two marks:			1	
Recovered trip three marks:				12
Fish examined for previous trip marks:				

Appendix 8. Age and sex distribution.

Year 2000

Brood Year	**1997**	**1996**	**1996**	**1995**	**1995**	**1994**		
Age	0.2	0.3	1.2	1.3	2.2	2.3	Male	Female
Percent	0.4	0.0	17.7	78.9	1.9	1.1	55.3	44.7

Year 1999

Brood Year	**1996**	**1995**	**1995**	**1994**	**1994**	**1993**		
Age	0.2	0.3	1.2	1.3	2.2	2.3	Male	Female
Percent	0.0	0.0	49.7	49.7	0.0	0.6	56.0	44.0

Year 1998

Brood Year	**1995**	**1994**	**1994**	**1993**	**1993**	**1992**		
Age	0.2	0.3	1.2	1.3	2.2	2.3	Male	Female
Percent	0.0	0.0	43.6	54.0	1.3	1.0	53.0	47.0

Year 1997

Brood Year	**1995**	**1993**	**1993**	**1992**	**1992**	**1991**		
Age	0.2	0.3	1.2	1.3	2.2	2.3	Male	Female
Percent	0.0	0.3	34.9	56.0	6.8	2.0	48.6	51.4

Average length by age class, mm:

Age:	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**
2000	454	na	345	507	562	na	507	563
1999	na	na	346	485	541	na	na	543
1998	na	na	353	491	545	338	497	548
1997	na	535	365	504	554	380	496	557
Average:	454	535	352	497	551	359	500	553

Appendix 9. Mark-recapture data form.

Sitkoh Lake Live Sockeye Mark-Recapture Project Data Form (Version 2000a)

Date: Circle---> Trip # : one two three four Day # : one two

Samplers:

Set #	Hour	**New Fish:** Marked w/	**Recaptured Fish:** Trip 1 (Ad+LA)	Trip 2 (Ad+LV)	Trip 3 (Ad+Dorsal)	Trip 4 (Ad+Anal)	Total Recaps	Total Caught
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
Total								

- Mark: Trip#1 adipose+left axillary, Trip#2 ad.+left ventral, Trip#3 ad.+dorsal (last four rays), Trip#4 ad.+anal
- Mark **all** recaptures from previous trip(s) with the current trip's mark.
- On "Day One", mark and examine for marks **only live fish** expected to be alive on 2nd day of trip.
- On "Day One" please don't record recaptures of fish marked **that** day.
- On "Day Two" **all** new and recaptured fish should be given a left opercule punch (lower trips 1&3, upper trips 2&4).
- On "Day Two" please don't record recaptures of fish that were opercule punched **that** day.